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Suzuki

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(54) **MEASURING APPARATUS**

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G01N 21/00	(2006.01)
G01N 29/00	(2006.01)
G01N 21/17	(2006.01)
A61B 5/00	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***G01N 21/1702*** (2013.01); ***A61B 5/0095*** (2013.01); *A61B 5/4312* (2013.01); *A61B 8/485* (2013.01); ***G01N 21/4795*** (2013.01); *G01N 21/49* (2013.01); *G01N 2021/1787* (2013.01); *G01N 2201/0697* (2013.01)

(58) **Field of Classification Search**

CPC A61B 5/0095; A61B 5/4312; A61B 8/485; G01N 21/1702; G01N 21/4795; G01N 2021/1787; G01N 21/49; G01N 2201/0697

USPC 73/655, 643

See application file for complete search history.

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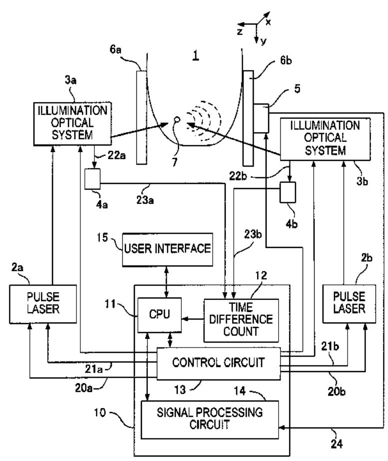
Primary Examiner — J M Saint Surin

(74) *Attorney, Agent, or Firm* — Fitzpatrick, Cella, Harper & Scinto

(57) **ABSTRACT**

A measuring apparatus includes: laser sources; and a control unit for outputting an excitation start signal that instructs the laser light sources to start excitation, and outputting an oscillation start signal to instruct the laser light sources to start oscillation after a predetermined time has elapsed from the output of the excitation start signal, so as to generate pulsed light from the laser light sources. The laser sources include a first laser source and a second laser source of which preparation time from the start of the excitation to the generation of the pulsed light is longer than that of the first laser source. The control unit sets timing to output the excitation start signal to the first laser source to follow timing to output the excitation start signal to the second laser source according to a difference of the preparation time between the first and second laser sources.

10 Claims, 12 Drawing Sheets



(51) **Int. Cl.**

G01N 21/47	(2006.01)
A61B 8/08	(2006.01)
G01N 21/49	(2006.01)

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Fig. 1

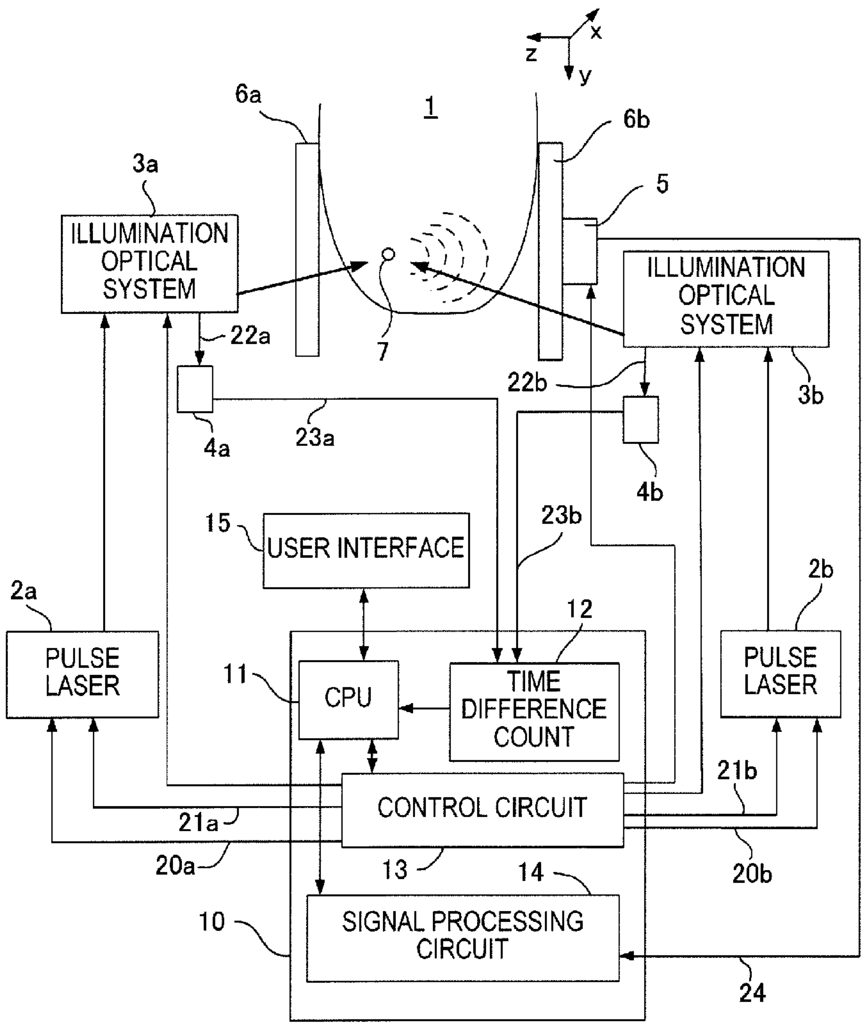
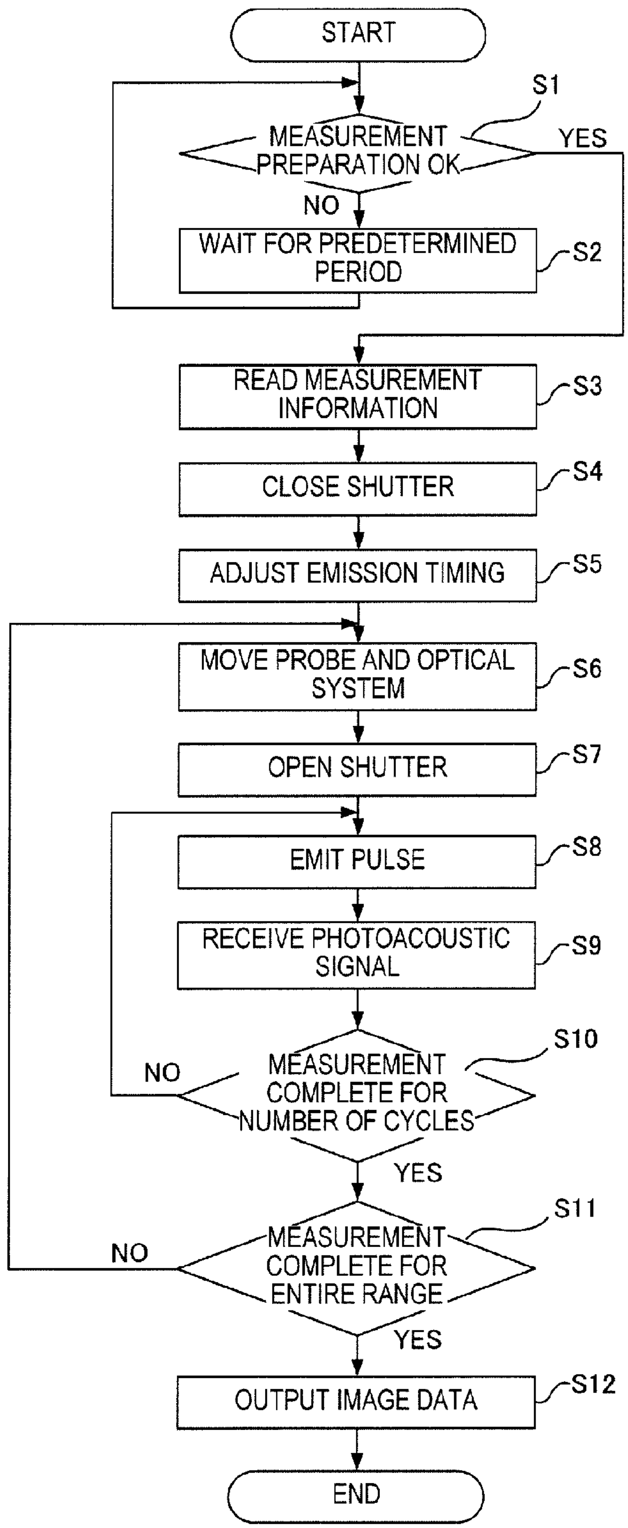
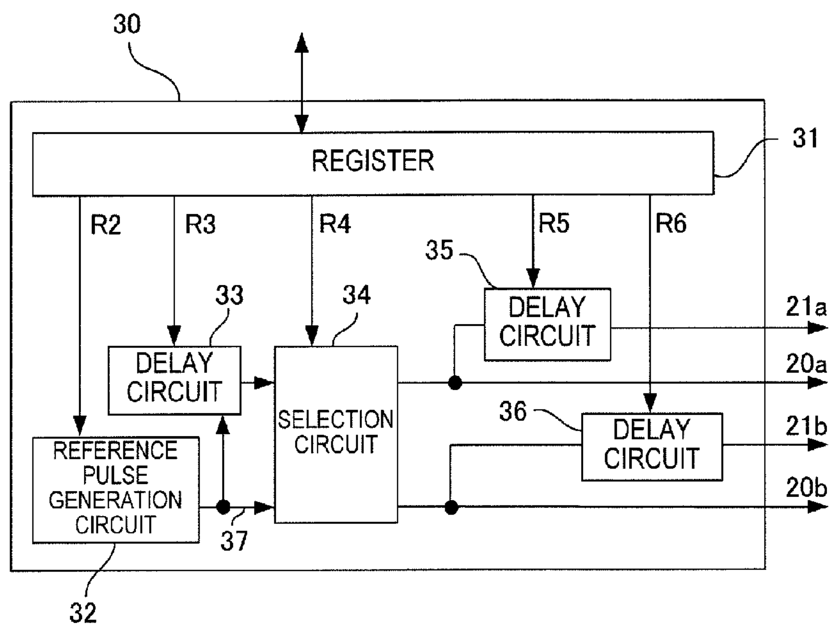

x
z
y
1
6a
6b
5
3a
ILLUMINATION OPTICAL SYSTEM
ILLUMINATION OPTICAL SYSTEM
7
22a
22b
3b
4a
23a
4b
23b
15
USER INTERFACE
2a
2b
12
PULSE LASER
PULSE LASER
11
CPU
TIME DIFFERENCE COUNT
CONTROL CIRCUIT
21a
21b
20a
20b
13
14
10
SIGNAL PROCESSING CIRCUIT
24

Fig. 2



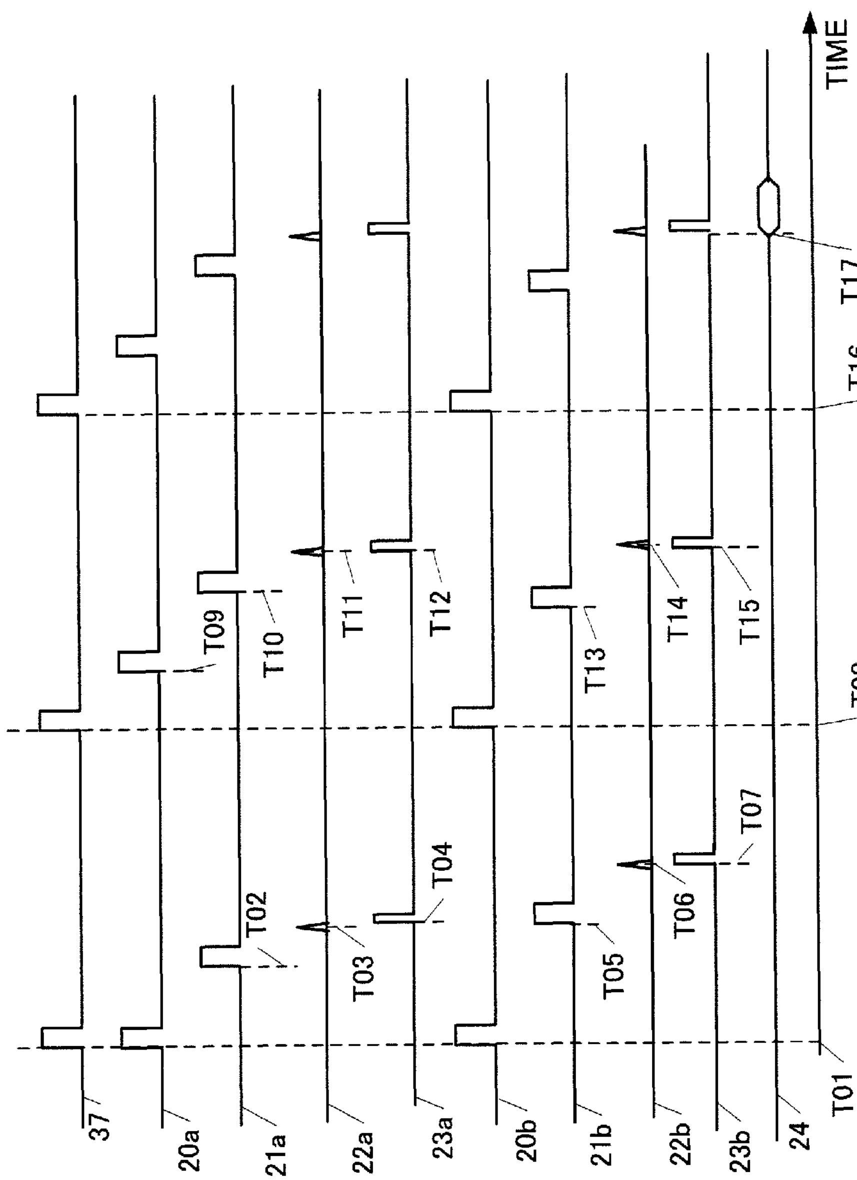
START
S1
MEASUREMENT PREPARATION OK
YES
NO
WAIT FOR PREDETERMINED PERIOD
S2
READ MEASUREMENT INFORMATION
S3
CLOSE SHUTTER
S4
ADJUST EMISSION TIMING
S5
MOVE PROBE AND OPTICAL SYSTEM
S6
OPEN SHUTTER
S7
EMIT PULSE
S8
RECEIVE PHOTOACOUSTIC SIGNAL
S9
MEASUREMENT COMPLETE FOR NUMBER OF CYCLES
S10
NO
YES
MEASUREMENT COMPLETE FOR ENTIRE RANGE
S11
NO
YES
OUTPUT IMAGE DATA
S12
END

Fig. 3



30
REGISTER
31
R2
R3
R4
R5
R6
35
DELAY CIRCUIT
33
34
DELAY CIRCUIT
SELECTION CIRCUIT
21a
20a
36
DELAY CIRCUIT
21b
REFERENCE PULSE GENERATION CIRCUIT
20b
37
32

Fig. 4



TIME
37
20a
21a
22a
23a
20b
21b
22b
23b
24
T01
T02
T03
T04
T05
T06
T07
T08
T09
T10
T11
T12
T13
T14
T15
T16
T17

Fig. 5

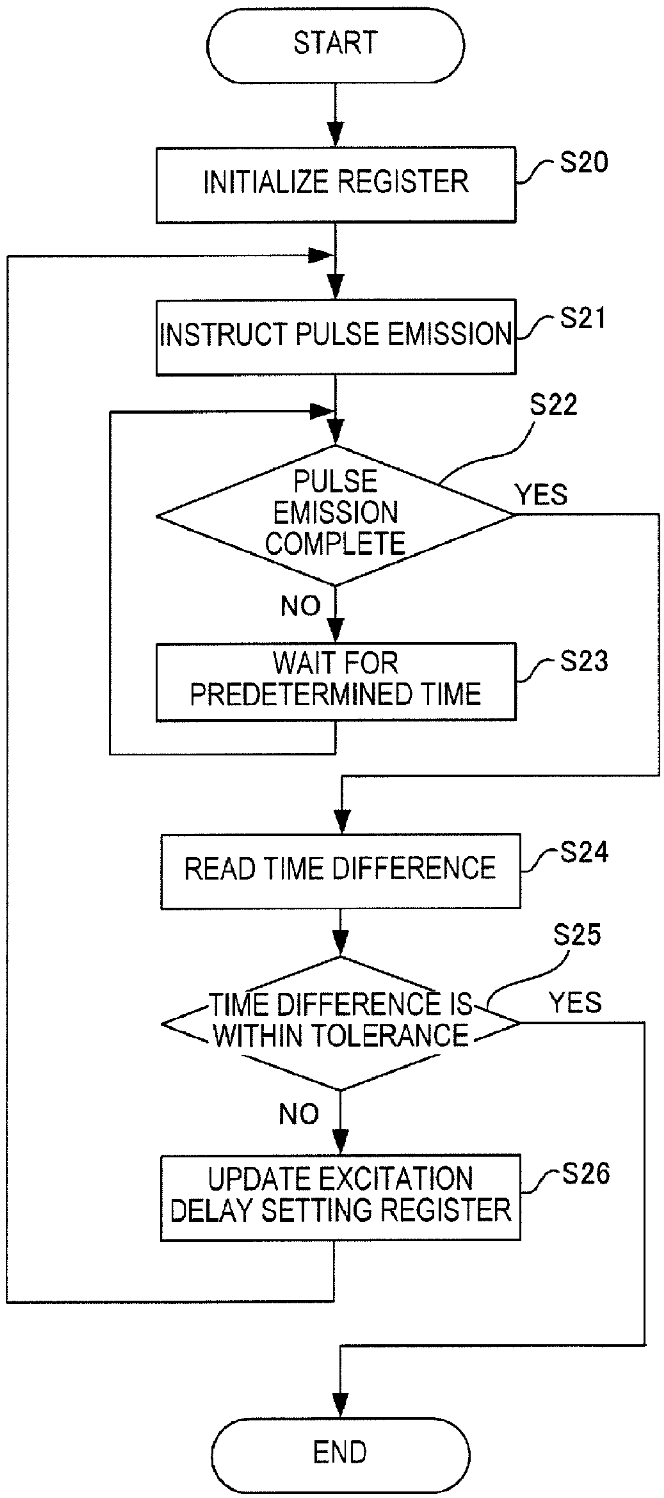

START
INITIALIZE REGISTER
S20
INSTRUCT PULSE EMISSION
S21
S22
PULSE EMISSION COMPLETE
YES
NO
WAIT FOR PREDETERMINED TIME
S23
READ TIME DIFFERENCE
S24
S25
TIME DIFFERENCE IS WITHIN TOLERANCE
YES
NO
UPDATE EXCITATION DELAY SETTING REGISTER
S26
END

Fig. 6A

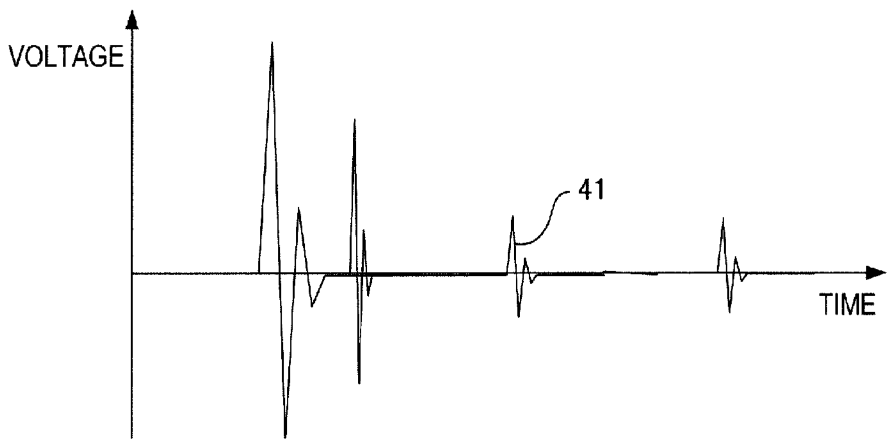


Fig. 6B

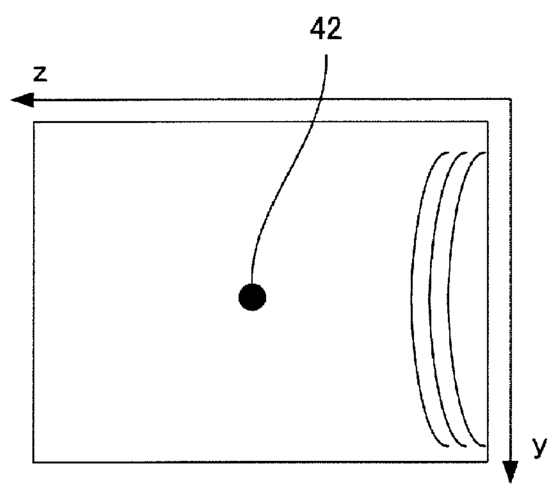


Fig. 7

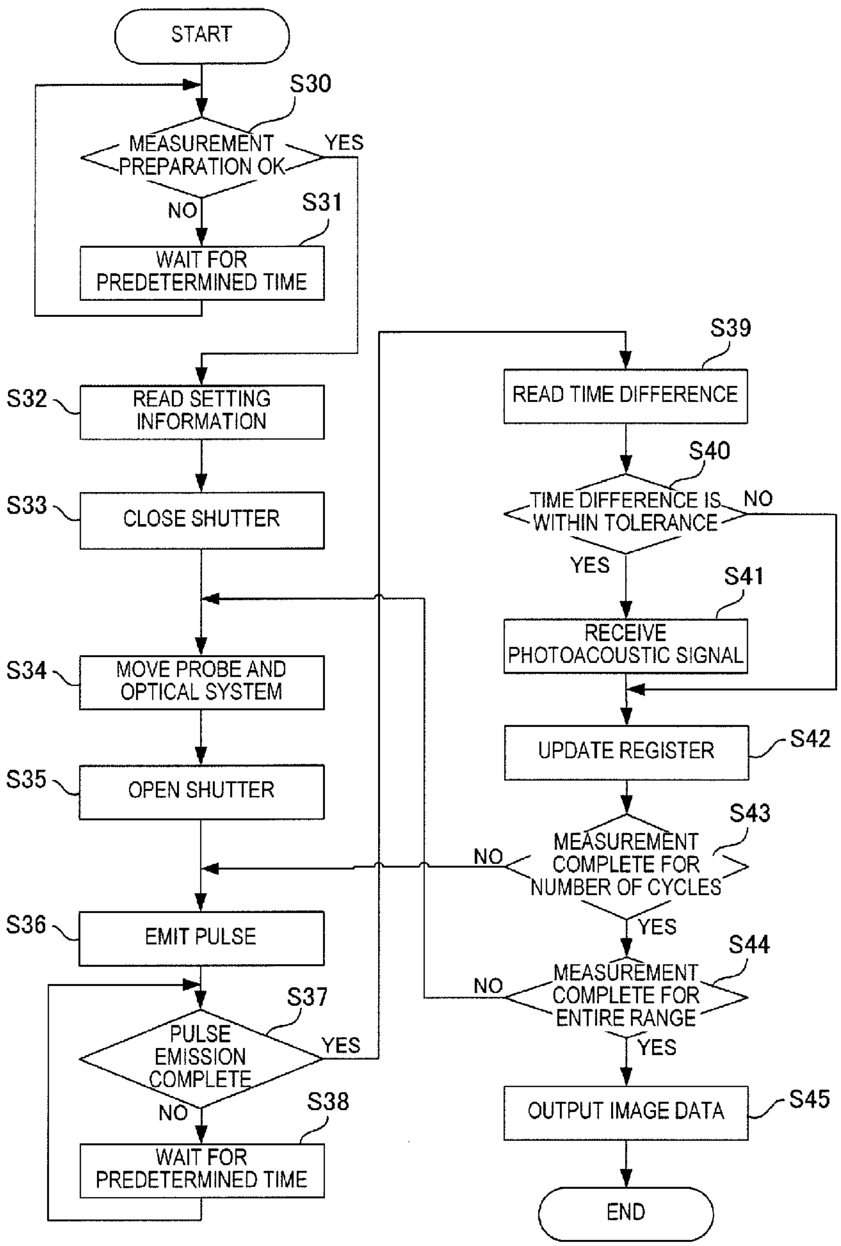

START
S30
MEASUREMENT PREPARATION OK
YES
NO
S31
WAIT FOR PREDETERMINED TIME
S32
READ SETTING INFORMATION
S33
CLOSE SHUTTER
S34
MOVE PROBE AND OPTICAL SYSTEM
S35
OPEN SHUTTER
S36
EMIT PULSE
S37
PULSE EMISSION COMPLETE
YES
NO
S38
WAIT FOR PREDETERMINED TIME
S39
READ TIME DIFFERENCE
S40
TIME DIFFERENCE IS WITHIN TOLERANCE
NO
YES
S41
RECEIVE PHOTOACOUSTIC SIGNAL
S42
UPDATE REGISTER
S43
MEASUREMENT COMPLETE FOR NUMBER OF CYCLES
NO
YES
S44
MEASUREMENT COMPLETE FOR ENTIRE RANGE
NO
YES
S45
OUTPUT IMAGE DATA
END

Fig. 8

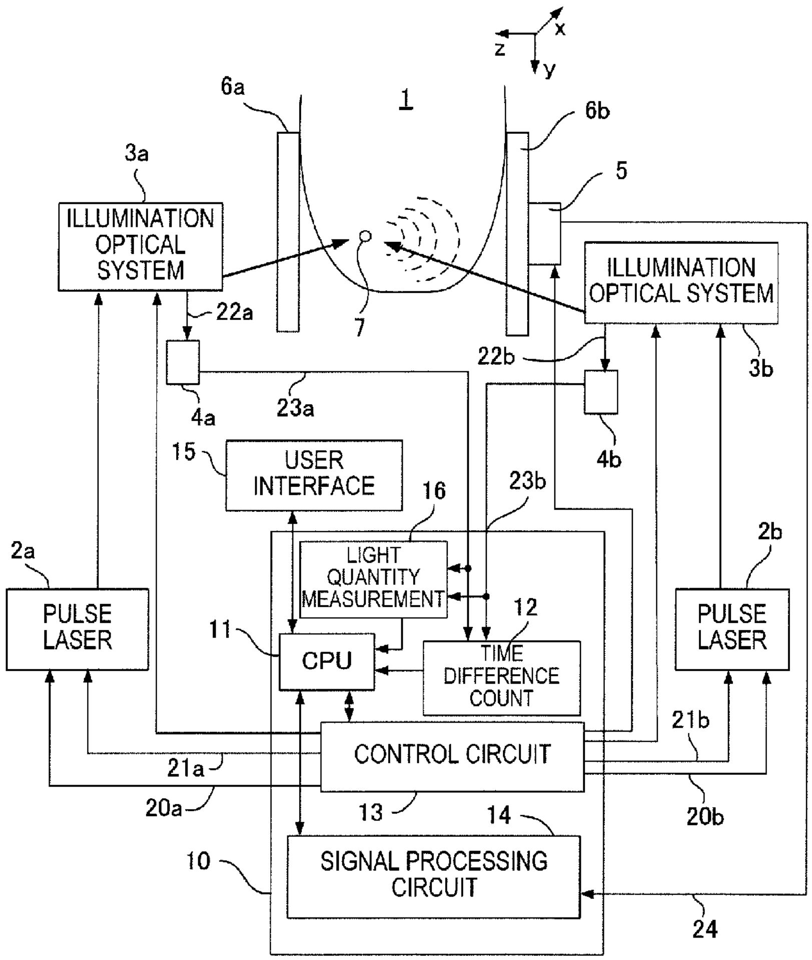

x
z
y
1
6a
6b
3a
5
ILLUMINATION OPTICAL SYSTEM
ILLUMINATION OPTICAL SYSTEM
7
22a
22b
3b
4a
23a
4b
15
USER INTERFACE
16
23b
2a
LIGHT QUANTITY MEASUREMENT
2b
PULSE LASER
12
PULSE LASER
11
CPU
TIME DIFFERENCE COUNT
21b
CONTROL CIRCUIT
21a
20a
13
14
20b
10
SIGNAL PROCESSING CIRCUIT
24

Fig. 9

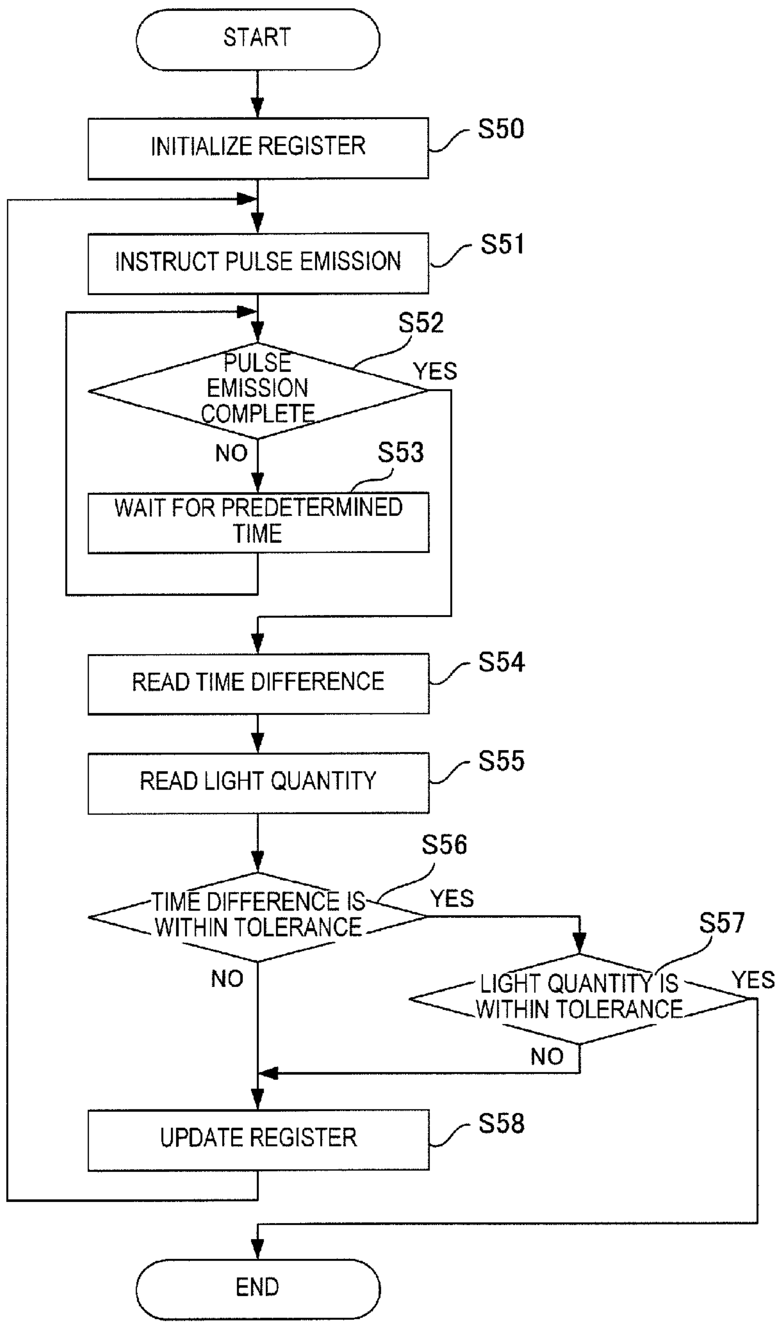

START
INITIALIZE REGISTER
S50
INSTRUCT PULSE EMISSION
S51
PULSE EMISSION COMPLETE
S52
YES
NO
WAIT FOR PREDETERMINED TIME
S53
READ TIME DIFFERENCE
S54
READ LIGHT QUANTITY
S55
TIME DIFFERENCE IS WITHIN TOLERANCE
S56
YES
NO
LIGHT QUANTITY IS WITHIN TOLERANCE
S57
YES
NO
UPDATE REGISTER
S58
END

Fig. 10

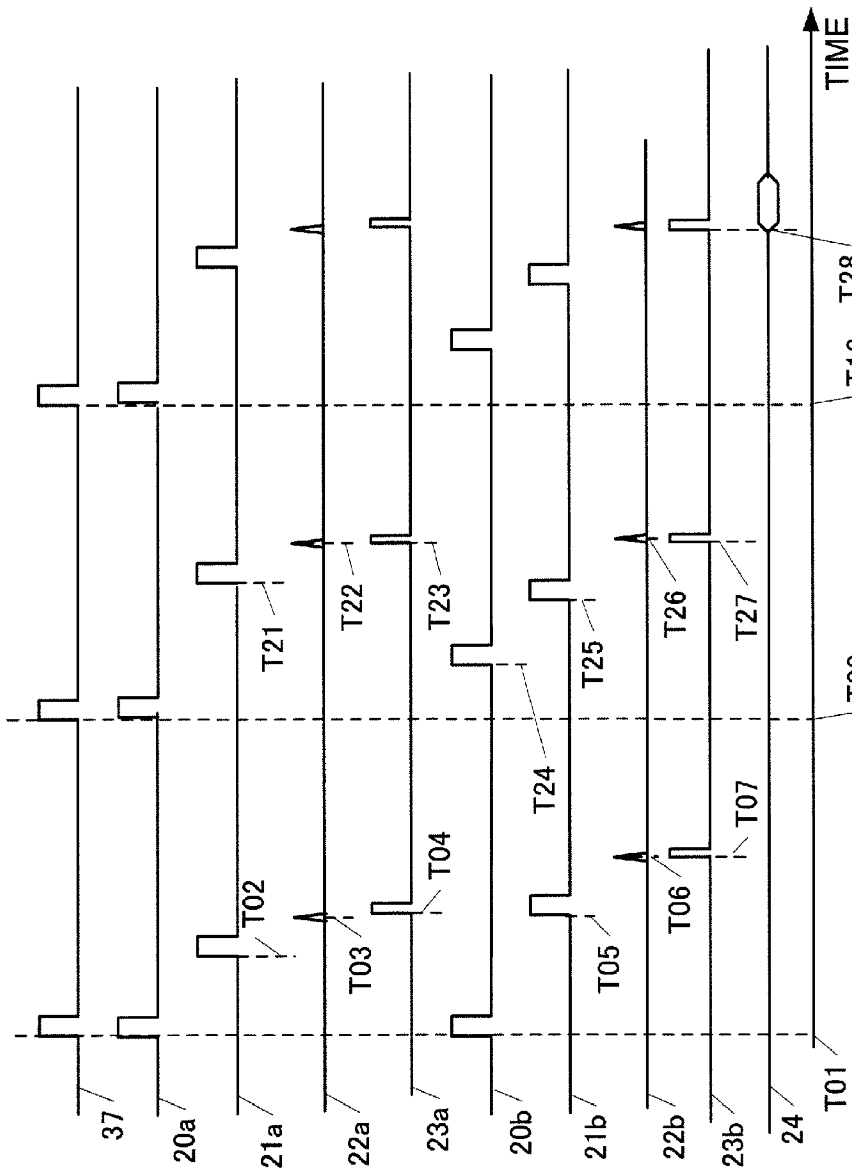

TIME
37
20a
21a
22a
23a
20b
21b
22b
23b
24
T01
T02
T03
T04
T05
T06
T07
T08
T16
T21
T22
T23
T24
T25
T26
T27
T28

Fig. 11A

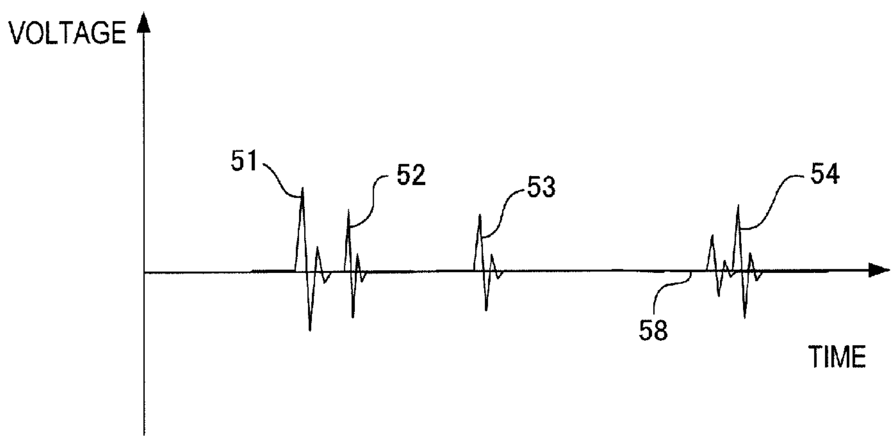


Fig. 11B

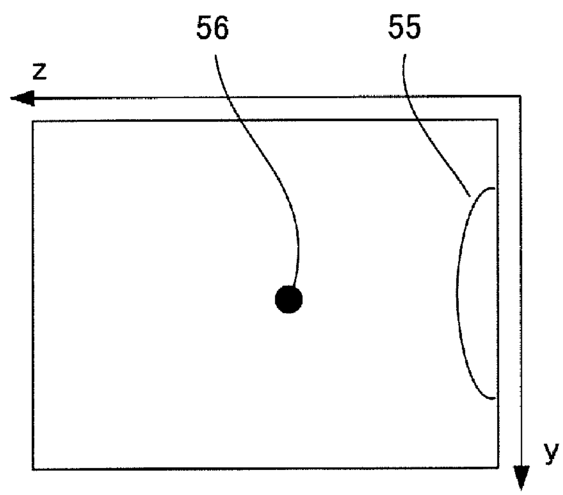


Fig. 12A

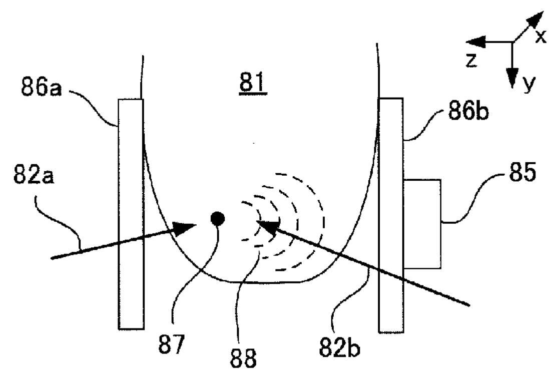


Fig. 12B

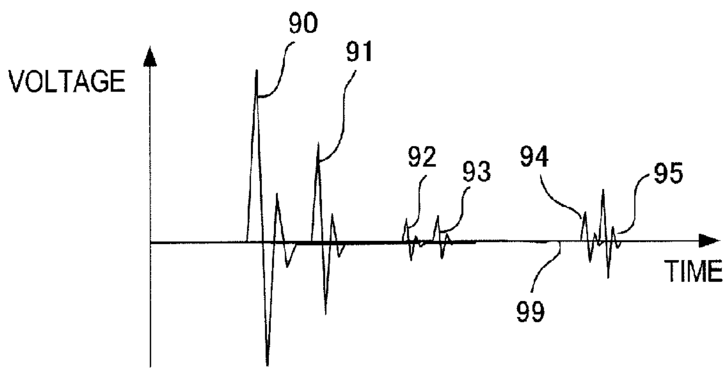
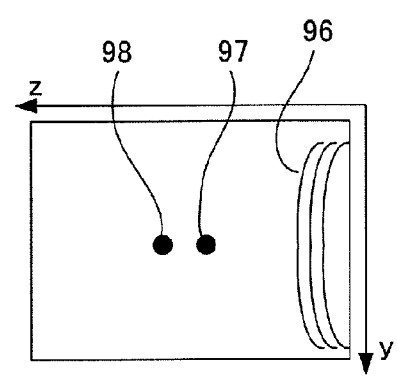


Fig. 12C



MEASURING APPARATUS

TECHNICAL FIELD

The present invention relates to a measuring apparatus for measuring spectral characteristics inside a biological tissue using a photoacoustic effect.

BACKGROUND ART

Many measuring apparatuses, in which a pulsed light is irradiated onto a biological object, a photoacoustic wave generated from inside the biological object is received by a probe, and the forms and functions inside the biological tissue are displayed as images, have been proposed in medical fields. This technology is called "photoacoustic tomography (PAT) ". In such an apparatus, the intensity of the light irradiated into the biological tissue attenuates while propagating inside the biological tissue due to absorption and scattering, hence only very little light reaches the depth of the tissue. As a result, photoacoustic waves are generated inside the biological tissue, and electric signals (photoacoustic signals) converted by the probe become weak. To prevent this, a Q switch is installed in the light source to perform rapid oscillation, so that the quantity of pulsed light is increased, and a higher quantity of light reaches the depth.

An apparatus, in which a plurality of light sources are installed so as to increase the quantity of light that reaches the depth of a subject by simultaneously irradiating pulsed light onto the subject from both sides thereof, has also been proposed in Japanese Patent Application Laid-Open No. 2010-017426.

An example of the conventional measuring apparatus will be described with reference to FIG. **12**A. FIG. **12**A shows a configuration of the conventional measuring apparatus. The reference numeral **81** is a biological tissue, that is a subject, **82***a* and **82***b* are pulsed lights, and **87** is a light absorbing area existing inside the subject. The light absorbing area refers to an area which absorbs energy of the pulsed light, and generates a photoacoustic wave efficiently, and an example is a blood vessel. **88** is a photoacoustic wave generated from the light absorbing area **87**, **85** is a probe for converting the photoacoustic wave **88** into an electric signal, and **86***a* and **86***b* are plate members for securing the subject **81**. A direction from the probe **85** to the subject **81** is a Z direction, a vertical direction from top to bottom is a Y direction, and an X direction is a horizontal direction which is orthogonal to the Z direction and the Y direction. If the pulsed lights **82***a* and **82***b* are irradiated onto the subject **81**, the photoacoustic wave **88** is generated from the light absorbing area **87**. This wave is converted into an electric signal (photoacoustic signal) by the probe **85**, and is then converted into a diagnostic image by an electric circuit, which is not illustrated, and is output. The timings of irradiating the pulsed lights **82***a* and **82***b* and the timings of receiving the photoacoustic signals are controlled by a controller, which is not illustrated.

A laser processing apparatus which can control the emission timings of a plurality of pulsed lights has also been proposed in Japanese Patent Application Laid-Open No. 2000-343256. Japanese Patent Application Laid-Open No. 2000-343256 discloses a method for adjusting the emission timings of two pulsed lights by changing a start timing of a pulse laser oscillation.

CITATION LIST

Patent Literature

[PTL 1]

Japanese Patent Application Laid-Open No. 2010-017426

[PTL 2]

Japanese Patent Application Laid-Open No. 2000-343256

SUMMARY OF THE INVENTION

Pulsed light sources have individual differences and are subject to aged deterioration. Therefore even if a control signal is transmitted to a plurality of light sources to irradiate a pulsed light at a same timing, the irradiation timings may actually be discrepant. If the timings of a plurality of pulsed lights irradiated onto a subject are discrepant, a plurality of photoacoustic waves are generated from a same location in the subject, and an artifact is generated on a diagnostic image.

It is possible to change the oscillation start timings of the two pulse lasers, as disclosed in Japanese Patent Application Laid-Open No. 2000-343256, in order to decrease artifacts. In this case however, energy to be stored in the laser medium fluctuates, and the quantity of light in each pulse emission fluctuates. Therefore in the case of a measuring apparatus which generates a diagnostic image using a photoacoustic wave generated by irradiating a plurality of pulsed lights for a plurality of times, the diagnostic image may be uneven.

With the foregoing in view, the present invention provides a technology to decrease a discrepancy of the emission timings of light sources, and decrease the artifacts in the diagnostic image in a measuring apparatus having a plurality of light sources.

The present invention provides a measuring apparatus for obtaining information from a subject, using a photoacoustic effect, the apparatus including: a plurality of laser sources for generating pulsed light; a control unit for outputting an excitation start signal that instructs the laser light sources to start excitation, and outputting an oscillation start signal to instruct the laser light sources to start oscillation after a predetermined time has elapsed from the output of the excitation start signal, so as to generate pulsed light from the laser light sources; an acoustic wave receiving unit for receiving an acoustic wave generated in the subject by the irradiation of the pulsed light; and a signal processing unit for generating information from the subject, using a signal which is output from the acoustic wave receiving unit, wherein the plurality of laser sources include a first laser source and a second laser source of which preparation time from the start of the excitation to the generation of the pulsed light is longer than that of the first laser source, and the control unit sets timing to output the excitation start signal to the first laser source to follow timing to output the excitation start signal to the second laser source according to a difference of the preparation time between the first laser source and the second laser source.

According to the present invention, image quality can be improved by decreasing the discrepancy of emission timings among light sources, and decreasing the artifacts in the diagnostic image.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF DRAWINGS

[FIG. **1**]

FIG. **1** is a block diagram depicting first example of the present invention.

[FIG. **2**]

FIG. **2** is a flow chart according to first example of the present invention.

[FIG. 3]

FIG. **3** is a block diagram depicting a control signal generation circuit according to first example of the present invention.

[FIG. 4]

FIG. **4** is a timing chart according to first example of the present invention.

[FIG. 5]

FIG. **5** is a flow chart of an emission timing adjustment processing according to first example of the present invention.

[FIG. 6A]

FIG. **6**A shows an example of a photoacoustic signal waveform according to first example of the present invention.

[FIG. 6B]

FIG. **6**B shows an example of a diagnostic image according to first example of the present invention.

[FIG. 7]

FIG. **7** is a flow chart according to second example of the present invention.

[FIG. 8]

FIG. **8** is a block diagram according to third example of the present invention.

[FIG. 9]

FIG. **9** is a flow chart of an emission timing adjustment processing according to third example of the present invention.

[FIG. 10]

FIG. **10** is a timing chart according to third example of the present invention.

[FIG. 11A]

FIG. **11**A shows an example of a photoacoustic signal waveform according to third example of the present invention.

[FIG. 11B]

FIG. **11**B shows an example of a diagnostic image according to third example of the present invention.

[FIG. 12A]

FIG. **12**A shows an example of a conventional measuring apparatus.

[FIG. 12B]

FIG. **12**B shows an example of a photoacoustic signal waveform of a conventional measuring apparatus.

[FIG. 12C]

FIG. **12**C shows an example of a diagnostic image of a conventional measuring apparatus.

DESCRIPTION OF EMBODIMENTS

FIRST EXAMPLE

(General Configuration)

FIG. **1** is a block diagram depicting a first example of a measuring apparatus according to the present invention. In FIG. **1**, **1** is a subject and a part of a body of a subject person. For example, if the measuring apparatus is used for the diagnosis of breast cancer, a breast is the subject. This measuring apparatus has a plurality of (two in this example) pulse laser sources **2***a* and **2***b*. Hereafter the pulse laser source **2***a* is also referred to as a first laser source, and the pulse laser source **2***b* as a second laser source. The pulse laser sources **2***a* and **2***b* are light sources for generating pulsed light, and are constituted by a YAG laser, a titanium-sapphire laser or the like. The pulse laser sources **2***a* and **2***b* have a flash lamp as a means for exciting the laser medium inside the pulse laser source. Each pulse laser source **2***a* and **2***b* has a Q switch. The flash lamp and the Q switch can be externally controlled electrically. If the Q switch is turned ON after turning the flash lamp ON and storing the excitation energy in the laser medium, a pulsed light having high energy, called a giant pulse, is output. The time required from the start of the excitation to the generation of the pulsed light (called "preparation time") depends on the individual difference of the pulse laser source, aged deterioration, model difference or the like. In this example, it is assumed that the preparation time is longer in the pulse laser source **2***b* than in the pulse laser source **2***a*.

3*a* and **3***b* are illumination optical systems for guiding the pulsed lights generated in the pulse laser sources **2***a* and **2***b* to the subject **1**, and are constituted by a mirror, beam splitter and shutter or the like. **4***a* and **4***b* are optical sensors for detecting a pulsed light, and are constituted by a photo diode and an amplifier circuit respectively. The optical sensors **4***a* and **4***b* are disposed in positions where a part of each pulsed light, which passes through the illumination optical systems **3***a* and **3***b*, enters respectively. Each of the illumination optical system **3***a* and **3***b* reflects the pulsed light using a mirror inside, and guides most of the reflected light to the subject **1**, but transmitted light partially exists. This transmitted light enters the optical sensors **4***a* and **4***b*.

7 shows an area of which light absorption is high (called the light absorbing area or light absorber) existing inside the subject. If a pulsed light is irradiated onto the light absorbing area **7**, a photoacoustic wave is generated due to a photoacoustic effect. The photoacoustic effect is a phenomenon where an acoustic wave is generated from the light absorbing area **7**, which expands and contracts by absorbing light energy. This acoustic wave is an elastic wave, such as an ultrasonic wave.

6*a* and **6***b* are plate members for compressing and holding the subject **1**. The subject **1** is stretched thin by the plate members **6***a* and **6***b*, so that the pulsed light can reach inside. **5** is a probe which receives a photoacoustic wave generated inside the subject, and converts the photoacoustic wave into an electric signal (photoacoustic signal). The probe is constituted by a two-dimensional ultrasonic sensor array, for example.

10 is a controller for receiving a photoacoustic signal which is output from the probe **5** and controlling the operation of the pulse laser sources **2***a*, and **2***b*, the illumination optical systems **3***a* and **3***b*, and the probe **5**. The controller **10** encloses a CPU **11**, a time difference counting circuit **12**, a control circuit **13** and a signal processing circuit **14**. The CPU **11** is constituted by a built-in microcomputer and software to control the operation of the entire measuring apparatus. The CPU **11** has an embedded memory, so as to save the setting information of the measuring apparatus.

The time difference counting circuit **12** is a circuit for receiving electric pulse signals from the optical sensors **4***a* and **4***b*, and measuring the time difference thereof. This circuit is comprised of a comparison circuit, a counter circuit and a clock generation circuit, and determines the detection of a pulsed light when voltage of the electric pulse signal rises exceeding a predetermined value. The time difference counting circuit **12** activates the counter circuit at each clock cycle, from the rise of one electric pulse signal to the rise of the other electric pulse signal. Then the time difference counting circuit **12** records the sequence of rises of electric pulse signals from the optical sensors **4***a* and **4***b*, and the difference of the rise time values between the electric pulse signals.

The control circuit **13** controls a timing of turning ON the flash lamp of each pulse laser source **2***a* and **2***b* and a timing of oscillation of the Q switch based on the register values which are set by the CPU **11**. The control circuit **13** also controls the switching of the shutter inside the illumination optical system **3***a* and **3***b*, and controls whether the pulsed light reaches the subject **1** or not.

The ends of the illumination optical systems **3***a* and **3***b* and the probe **5** are attached to an XY stage, which is not illustrated, so as to move relatively with respect to the subject **1**. Thereby the pulsed light is irradiated onto and the photoacoustic wave is received from many points on the surface of the subject **1**, and photoacoustic signals are obtained from a wide range.

The signal processing circuit **14** is a circuit to receive a photoacoustic signal from the probe **5**, and to perform amplification, signal processing and image reconstruction. The signal processing circuit **14** is comprised of an operational amplifier, an A/D converter, and an FPGA among others. **15** is a user interface for a user to control the operation of the measuring apparatus and change settings, and to display diagnostic images to the user. The user interface **15** is comprised of an input device such as a keyboard, and an output device such as a display.

For the control signals to control the pulse laser sources **2***a* and **2***b*, an excitation start signal to instruct the start of excitation, and an oscillation start signal to instruct the start of the oscillation are used. The excitation start signal is a control signal for turning ON the flash lamp inside the light source, and the oscillation start signal is a control signal for closing the Q switch and generating a giant pulse by rapid oscillation. Both of these signals are DC 5V digital pulse signals. In FIG. **1**, **20***a* is the excitation start signal for the pulse laser source **2***a*, and **21***a* is the oscillation start signal for the pulse laser source **2***a*. **20***b* is the excitation start signal for the pulse laser source **2***b*, and **21***b* is the oscillation start signal for the pulse laser source **2***b*.

22*a* is a pulsed light which enters the illumination optical system **3***a* to the optical sensor **4***a*, and **22***b* is a pulsed light which enters from the illumination optical system **3***b* to the optical sensor **4***b*. **23***a* is an electric pulse signal which is output from the optical sensor **4***a*, and **23***b* is an electric pulse signal which is output from the optical sensor **4***b*. These are analog pulse signals. **24** is a photoacoustic signal which is output from the probe **5**.

In this example, the CPU **11** and the control circuit **13** correspond to the control unit of the present invention, the probe **5** corresponds to the acoustic wave receiving unit of the present invention, and the signal processing circuit **10** corresponds to the signal processing unit of the present invention. The optical sensors **4***a* and **4***b* and the time difference counting circuit **12** correspond to the detection unit of the present invention, which detects the difference of the pulsed light generation timings.

(Operation Flow)

FIG. **2** shows an operation flow of the measuring apparatus to be executed by the controller **10**. In step S**1**, the CPU **11** checks whether the measuring is ready. If the subject **1** is secured between the plate members **6***a* and **6***b*, the CPU **11** determines that the measurement is ready, and advances to step S**3**. If the measurement is not ready, the CPU **11** advances to step S**2**, waits for a predetermined time, then returns to step S**1**.

Then in step S**3**, the CPU **11** reads the setting information, which the user specified via the user interface **15**, and records the information to the internal memory. The setting information is, for example, a number of irradiation cycles at a same measurement position, a measurement range and wavelength of a pulsed light.

Then in step S**4**, the CPU **11** transmits a control signal to close the shutters (light interrupting units) disposed inside the illumination optical systems **3***a* and **3***b* via the control unit **13**. Thereby the pulsed lights from the pulse laser sources **2***a* and **2***b* enter the optical sensors **4***a* and **4***b* respectively, but do not reach the subject **1**. Then in step S**5**, the CPU **11** adjusts the timings of the control signals for the pulse laser sources **2***a* and **2***b* via the control unit **13**. The method for adjusting the timings will be described later.

In step S**6**, the CPU **11** drives the XY stage via the control unit **13**, and moves the ends of the illumination optical systems **3***a* and **3***b* and the probe **5** to the measurement position of the subject **1**. Then in step S**7**, the CPU **11** transmits a control signal to open the shutters disposed inside the illumination optical systems **3***a* and **3***b* respectively via the control circuit **13**. Thereby the pulsed lights from the pulse laser sources **2***a* and **2***b* can reach the optical sensors **4***a* and **4***b* and the subject **1** respectively.

Then in step S**8**, the CPU **11** transmits a control signal to the pulse laser sources **2***a* and **2***b* via the control circuit **13** to generate pulsed lights. The control circuit **13** rises the excitation start signals and the oscillation start signals of the pulse laser sources **2***a* and **2***b* at the timings adjusted in step S**5**. As a result, the plurality of pulsed lights can be irradiated onto the subject **1** almost at the same time, regardless the individual difference of the plurality of pulse laser sources.

The photoacoustic wave generated inside the subject **1** is converted into an electric signal by the probe **5**, and is transferred to the signal processing circuit **14**. In step S**9**, the signal processing circuit **14** inputs the photoacoustic signals for a predetermined time, and stores the signals in the internal memory after the electric pulse signal from the optical sensor **4***a* or **4***b* rises. In this case, signals generated at a same position on the subject are arithmetic averaged to decrease the influence of noise.

Then in step S**10**, the CPU **11** determines whether a number of times of saving the photoacoustic signals into the internal memory reached the number of irradiation cycles read in step S**3**. Processing advances to step S**11** if the read value is reached, and returns to step S**8** if not reached. For example, if a value **3** is read in step S**3** as the number of irradiation cycles, the processing in step S**8** and step S**9** is repeated three times, and then processing advances to step S**11**.

Then in step S**11**, the CPU **11** determines whether measurement is completed for the entire measurement range of the subject **1**. The measurement range was read in step S**3**. If measurement is completed for the entire measurement range, processing advances to step S**12**. If there are positions where measurement is not completed, processing returns to step S**6** and continues. In step S**12**, the CPU **11** reconstructs the image based on the photoacoustic signal data at each measurement position stored in the internal memory of the signal processing circuit **14**, and outputs the diagnostic image, to indicate the spectral characteristics inside the subject **1**, to the user interface **15**.

(Control Signal Generation Circuit)

FIG. **3** is a block diagram of a portion of generating control signals **20***a*, **21***a*, **20***b* and **21***b* to the pulse laser sources **2***a* and **2***b* among the internal circuits of the control circuit **13**.

In FIG. **3**, **30** is a generation circuit for generating the control signals **20***a*, **21***a*, **20***b* and **21***b* to the pulse laser sources **2***a* and **2***b*. The generation circuit **30** is a logic circuit implemented on a device, such as an FPGA. **31** is a register which is read or written by the CPU **11**. The register **31** has five registers (R**2** to R**6**). R**2** is a control register which starts operation of the generation circuit **30**. R**3** is an excitation delay setting register which sets the delay time in a delay circuit **33**. R**4** is a selection setting register which sets an operation of a selection circuit **34**. R**5** is an oscillation delay setting register for the pulse laser source **2***a* which sets the delay time in a delay circuit **35**. R**6** is an oscillation delay setting register for the pulse laser source **2***b* which sets the delay time in a delay circuit **36**. **32** is a reference pulse generation circuit which outputs a reference pulse signal **37** to the delay circuit **33** and the selection circuit **34** at a predetermined frequency when the value of the control register R**2** is 1. In this example, it is assumed that the frequency of the reference pulse signal **37** is 10 Hz, and the pulse laser sources **2***a* and **2***b* can output pulsed lights at a 10 Hz frequency.

The delay circuit **33** is a circuit which delays the reference pulse signal **37** for the time specified by the excitation delay setting register R**3**, and outputs it to the selection circuit **34**. The unit of time is nano seconds. For example, if the set value of the excitation delay setting register R**3** is 2000, the delay circuit **33** delays the reference pulse signal **37** for 2 micro seconds, and outputs it.

The selection circuit **34** is a circuit which inputs the reference pulse signal **37** and the delayed pulse signal output from the delay circuit **33**, and outputs the excitation start signals **20***a* and **20***b* according to the value of the selection setting register R**4**. The selection setting register R**4** can take four values, **0** to **3**. If the value of the selection setting register R**4** is 0, the reference pulse signal **37** is output for the excitation start signal **20***a*, and the output signal from the delay circuit **33** is output for the excitation start signal **20***b*. If the value of the selection setting register R**4** is 1, the reference pulse signal **37** is output for the excitation start signal **20***b*, and the output signal from the delay circuit **33** is output for the excitation start signal **20***a*. If the value of the selection setting register R**4** is 2, the reference pulse signal **37** is output for the excitation start signal **20***a*, and no pulse signal is output for the excitation start signal **20***b*. If the value of the selection setting register R**4** is 3, the reference pulse signal **37** is output for the excitation start signal **20***b*, and no pulse signal is output for the excitation start signal **20***a*.

The delay circuit **35** is a circuit which delays the excitation start signal **20***a* for the time specified by the oscillation delay setting register R**5** for the pulse laser source **2***a*, and outputs the result as the oscillation start signal **21***a*. The unit of the time is assumed to be nano seconds. The delay circuit **36** delays the excitation start signal **20***b* for the time (nano seconds) specified by the oscillation delay setting register R**6** for the pulse laser source **2***b*, and outputs the result as the oscillation start signal **21***b*.

In this way, the timings of the excitation start signals **20***a* and **20***b* and the oscillation start signals **21***a* and **21***b* can be flexibly changed at high precision, by providing the delay circuits **33**, **35** and **36** as hardware inside the control circuit **13**, and allowing to change settings thereof via the user interface **15**. If both the pulse laser sources **2***a* and **2***b* are emitted, the pulse laser source to be excited first in time can be changed by changing the value of the selection setting register R**4** to 0 or 1. Operation to emit only one of the pulsed laser sources **2***a* and **2***b* can also be implemented by changing the value of the selection setting register R**4** to 2 or 3. Hereafter an operation in the case of emitting both the pulse laser sources **2***a* and **2***b* will be described.

(Emission Timing Adjustment)

The processing the CPU **11** performs during the emission timing adjustment processing in step S**5** in FIG. **2** will now be described with reference to FIG. **4** and FIG. **5**.

FIG. **4** is a time chart depicting a relationship of the control signals **20***a*, **21***a*, **20***b* and **21***b* to the pulse laser sources **2***a* and **2***b*, pulsed lights **22***a* and **22***b*, electric pulse signals **23***a* and **23***b* and the photoacoustic signal **24**. FIG. **5** is a flow chart showing details of the emission timing adjustment processing which the CPU **11** executes in step S**5**.

In step S**20**, the CPU **11** initializes the values of the registers R**2** to R**6** described in FIG. **3**. Here the values of the control register R**2**, the excitation delay setting register R**3** and the selection setting register R**4** are set to 0. The CPU **11** also sets the oscillation delay setting register R**5** for the pulse laser source **2***a* and the oscillation delay setting register R**6** for the pulse laser source **2***b* to pre-adjusted initial values. It is assumed that optimum values are determined based on the power consumption and quantity of the pulsed light when the pulse laser sources **2***a* and **2***b* are setup. In the description here, it is assumed that the value of the oscillation delay setting register R**5** for the pulse laser source **2***a* is set to 150000, and the oscillation delay setting register R**6** for the pulse laser source **2***a* is set to 152000, for example. The value of the oscillation delay setting register R**5** for the pulse laser source **2***a* determines the time for storing energy in the laser medium of the pulsed laser source **2***a* (excitation time), and is closely related to the light quantity of the pulsed light **22***a*. The same for the oscillation delay setting register R**6** for pulse laser source **2***b*, which is closely related to the light quantity of the pulsed light **22***b*. It is assumed that these values are predetermined depending on the size of the target light absorbing area **7** and the quantity of light that can be irradiated onto the subject **1**, and held in the memory of the CPU **11**.

Then in step S**21**, the CPU **11** sets the value of the control register R**2** to 1. Thereby the reference pulse signal **37** starts to be output from the reference pulse generation circuit **32** at a 10 Hz frequency (time T**01**).

At first, the value of the excitation delay setting register R**3** is initialized to 0, hence the output signal from the delay circuit **33** is also output at the same time with the reference pulse signal **37**. The value of the selection setting register R**4** is also initialized to 0, hence the excitation start signals **20***a* and **20***b* are output at the same timing. Thereby the flash lamps inside the pulse laser source **2***a* and **2***b* turn ON, energy of the laser medium is stored, and the excitation state is established. On the other hand, the value of the oscillation delay setting register R**5** for the pulse laser source **2***a* is set to 150000, hence, the oscillation start signal **21***a* is output when 150 micro seconds elapsed after the excitation start signal **20***a* (time T**02**). Due to this, the Q switch is turned ON in the pulse laser source **2***a*, the rapid amplification and the oscillation of the excitation energy occur, and the pulsed light **22***a* is output at several 100 nano seconds later (time T**03**). This timing is different depending on the pulse laser source and the wave length set value. The electric pulse signal **23***a* is output after several nano seconds of delay in the optical sensor **4***a* (time T**04**).

On the other hand, the value of the oscillation delay setting register R**6** for the pulse laser source **2***b* is set to 152000, so the oscillation start signal **21***b* is output when 152 micro seconds elapsed after the excitation start signal **20***b* (time T**05**). Thereby the Q switch turns ON in the pulse laser source **2***b*, and rapid amplification and the oscillation of excitation energy occur. Then the pulsed light **22***b* is output several 100 nano seconds later (time T**06**). After several nano seconds of delay in the optical sensor **4***b*, the electric pulse signal **23***b* is output (time T**07**).

The difference of rise time between the electric pulse signals **23***a* and **23***b*, that is, the value of "T**07**–T**04**" is measured and recorded by the time difference counting circuit **12** in nano second units. This time difference corresponds to the difference of the pulsed light generation timings between the two pulse laser sources **2***a* and **2***b*. Here it is assumed that if the electric pulse signal **23***a* rises before the electric pulse signal **23**b, a positive value is recorded. For example, if the electric pulse signal **23**a rises and then the electric pulse signal **23**b rises at 2.2 micro second later, 2200 [ns] is recorded as the time difference "T**07**–T**04**". If the electric pulse signal **23**b rises and then the electric signal **23**a rises at 2.2 micro seconds later, a –2200 [ns] is recorded as the time difference "T**07**–T**04**".

The CPU **11** enters the wait state during a period from time T**01** to time T**07**. In step S**22**, the CPU **11** accesses the time difference counting circuit **12** and determines whether the measurement of the time difference of the electric pulse signals **23**a and **23**b corresponding to the pulsed lights **22**a and **22**b generated in step S**21** has completed. If completed, processing advances to step S**24**. If not completed, processing advances to step S**23**, and returns to step S**22** after waiting for a predetermined time.

In step S**24**, the CPU **11** accesses the time difference counting circuit **12** and reads the value "T**07**–T**04**" as the time difference.

In step S**25**, the CPU **11** compares the time difference "T**07**–T**04**" with the tolerance of the timing discrepancy of the pulsed light, and determines whether the time difference is within the tolerance. It is assumed that this tolerance is determined in advance depending on the pulse widths of the pulsed light **22**a and the pulsed light **22**b, the frequency characteristics of the probe **5** and the like, and stored in the CPU **11**. The generation timings of the two pulsed lights **22**a and **22**b need not be exactly the same. It is sufficient only if the photoacoustic wave is not generated twice from one light absorbing area, therefore it is acceptable if the discrepancy of the generation timings is smaller than the width of the pulsed light, and the two pulsed lights overlap in the time direction. In the present example, a case of the time difference "T**07**–T**04**" is 2200 [ns] will be described as an example. In this example, the width of the pulsed light is approximately 10 [ns], and the tolerance is determined to be –10 [ns] or more 10 [ns] or less, so that the two pulsed lights overlap.

If the time difference "T**07**–T**04**" is within the tolerance, the CPU **11** determines that the generation timings of the two pulsed lights match, and ends the processing. In this case, the CPU **11** may write 0 in the control register so as to stop the reference pulse signal **37** once. If the time difference "T**07**–T**04**" is outside the tolerance, processing advances to step S**26**.

In step S**26**, the CPU **11** changes the setting of the control circuit **13** so that the time difference, measured by the time difference counting circuit **12**, is cancelled. The CPU **11** writes the absolute value of the time difference (T**07**–T**04**) read in step S**24** to the excitation delay setting register R**3**. If the value of "T**07**–T**04**" is 0 or more, the CPU **11** writes 1 to the selection setting register R**4**. If the value of "T**07**–T**04**" is negative, the CPU **11** writes 0 to the selection setting register R**4**. If the value of "T**07**–T**04**" is 2200, for example, the CPU **11** sets 2200 in the excitation delay setting register R**3**, and writes 1 to the selection setting register R**4**.

Then processing returns to S**21** and the CPU **11** continues processing. In this case, the reference pulse signal **37** is output at time T**08**, which is 100 milli seconds after time T**01**. If the value of the excitation delay setting register R**3** is 2200, a pulse signal is output from the delay circuit **33** at 2.2 micro seconds after time T**08** (time T**09**). Since the value of the selection setting register R**4** is 1, a pulse signal is output at time T**09** for the excitation start signal **20**a, and a pulse signal is output at time T**08** for the excitation start signal **20**b. In other words, the flash lamp of the pulse laser source **2**a starts to turn ON at 2.2 micro seconds after the flash lamp of the pulse laser source **2**b turns ON.

The value of the oscillation delay setting register R**5** for the pulse laser source **2**a is not changed in step S**26**. This means that the time difference "T**10**–T**09**" of the oscillation start signal **21**a and the excitation start signal **20**a remains at 150 micro seconds. If a pulse signal is output for the oscillation start signal **21**a at time T**10**, the Q switch turns ON in the pulse laser source **2**a, and rapid amplification and oscillation of the excitation energy occur. Then the pulsed light **22**a is output in at several 100 nano seconds later (time T**11**). After several nano seconds of delay in the optical sensor **4**a, the electric pulse signal **23**a is output (time T**12**).

On the other hand, the value of the oscillation delay setting register R**6** for the pulse laser source **2**b is not changed in step S**26** either. This means that the time difference "T**13**–T**08**" of the oscillation start signal **21**b and the excitation start signal **20**b remains at 152 micro seconds. If a pulse signal is output for the oscillation start signal **21**b at time T**13**, the Q switch turns ON in the pulse laser source **2**b, and rapid amplification and oscillation of the excitation energy occur, and the pulsed light **22**b is output at several 100 nano seconds later (time T**14**). After several nano seconds of delay in the optical sensor **4**b, the electric pulse signal **23**b is output (time T**15**).

By measuring the time difference due to the individual difference of the light source and the aged deterioration at the first emission, and shifting the start of the second excitation, the time difference "T**15**–T**12**" of the electric pulse signal **23**a and the electric pulse signal **23**b, that is the discrepancy of the emission timings, can be minimized. The fluctuation of the pulsed light quantity in each emission is decreased by keeping the time difference "T**10**–T**09**" and "T**13**–T**08**", between the excitation start and the oscillation start, constant.

If the time difference between the electric pulse signal **23**a and the electric pulse signal **23**b becomes within the tolerance by the timing control thus far, the emission timing adjustment processing ends. Then irradiation of the pulsed light onto the subject and reception of the photoacoustic wave are started by the processing in step S**6** and later in FIG. **2** (time T**16**). Since the CPU **11** does not change the register value in the control circuit **13** here, the pulse laser sources are controlled at the same timings from time T**08** to time T**16**. The reception of the photoacoustic signal starts synchronizing with the electric pulse signal **23**a or the electric pulse signal **23**b (time T**17**).

(Comparison with Prior Art)

After describing the problems of a conventional measuring apparatus with reference to FIG. **12**A to FIG. **12**C, the advantages of this example will be described. FIG. **12**B is an example of the photoacoustic signal which is output from a probe **85** of a conventional measuring apparatus shown in FIG. **12**A. The abscissa indicates time, and the ordinate indicates voltage. FIG. **12**C is an example of a diagnostic image created by converting the photoacoustic signal by the conventional measuring apparatus.

The emission timing and the light quantity of a pulse laser source fluctuates depending on the individual difference and the aged deterioration of the light source, or the wavelength of the pulsed light. If such a discrepancy of emission timings and discrepancy of light quantity are generated, an artifact is generated on the diagnostic image, and image quality drops.

First an artifact, due to the discrepancy of timings of pulsed lights **82**a and **82**b, will be described. If the timings of the two pulsed lights **82**a and **82**b are discrepant, a photoacoustic wave **88** is generated twice from one light absorbing area **87**. Since these photoacoustic waves reach the probe **85** at different timings, photoacoustic signals **92** and **93** are output from the probe **85** at two separate times. If such photoacoustic signals are received, a signal processing circuit misjudges that two light absorbing areas exist at different positions.

Hence the light absorbing area, which is at one location, is displayed as two separate images, **97** and **98**, in the diagnostic image.

An artifact due to the discrepancy of light quantity will be described next. When the pulsed light **82***b* is irradiated onto the subject **81**, a part thereof is absorbed by the surfaces of a plate member **86***b* and the subject **81**, and the photoacoustic waves are generated. Signals **90** and **91** generated by the photoacoustic waves are output first. If the quantity of the pulsed light **82***b* is too high, a strong photoacoustic wave is generated, and is reflected multiple times between the plate member **86***b* and the subject **81**, hence the noise signals **90** and **91** are generated for a long time. As a result, an artifact **96** is generated in the diagnostic image. If the light quantity of the pulsed lights **82***a* and **82***b* is too low, on the other hand, the photoacoustic wave **88** from the light absorbing area **87** becomes weak, and the images **97** and **98** in the diagnostic image blur.

When the pulsed light **82***a* is irradiated onto the subject **81**, a part thereof is absorbed by the surfaces of a plate member **86***a* and the subject **81**, and photoacoustic waves are generated. However signals **94** and **95** generated by these photoacoustic waves are output last, and the influence on the diagnostic image can be prevented by not using the signals after time **99** for generating a diagnostic image.

Now an example of a photoacoustic signal waveform and a diagnostic image according to this example is shown in FIG. **6**A and FIG. **6**B. FIG. **6**A is an example of the photoacoustic signal which is output from the probe. The abscissa indicates time, and the ordinate indicates voltage. FIG. **6**B is a diagnostic image created by converting the photoacoustic signal.

According to this example, the pulsed lights **22***a* and **22***b* are irradiated onto the subject **1** almost simultaneously at time T**17**. Due to this, the photoacoustic wave is generated only once from the light absorbing area **7**. Therefore corresponding the photoacoustic signal **41** and an image **42** in the diagnostic image are integrated into one. Since the energy of the two pulsed lights are simultaneously absorbed by the light absorbing areas **7**, a stronger photoacoustic wave is generated compared with the case of pulsed lights of which timings are discrepant. As a result, the voltage of the photoacoustic signal **41** is higher than those of the photoacoustic signals **92** and **93** measured by a conventional apparatus. It is also possible to enhance the contrast of the image **42** in the diagnostic image by this example, compared with those of images **97** and **98** in the case of the pulsed lights of which timings are discrepant.

(Variant Form)

In this example, a case of irradiating pulsed lights of the two pulse laser sources **2***a* and **2***b* from positions opposite the subject **1** was described for simplification, but a number of pulse laser sources may be three or more. The irradiating direction is not limited to the direction opposite the subject **1**. For example, the present invention can be applied to a case of disposing many illumination optical systems around the subject, and irradiating pulsed lights simultaneously from many directions.

In this example, a case of two identical pulse laser sources **2***a* and **2***b* was described, but the present invention can also be applied to a case of a plurality of pulse laser sources of which types are different. In this case, the discrepancy of timings of the pulsed lights, not only due to the individual difference of the pulsed laser sources, but also due to the difference of types of the plurality of pulse laser sources, can be prevented.

In FIG. **2** of this example, a case of adjusting the timings of the pulse laser sources after the measurement of the subject **1** is ready was described, but the sequence of the timing adjustment and other processing is not limited to this. For example, the subject **1** may be secured to the measurement position after the timing adjustment is performed first. In this case, the time of binding the subject **1** can be decreased, and burden on the subject person can be decreased.

If the pulse laser sources **2***a* and **2***b* allow the user to set the wavelength, frequency, energy to be supplied and the like, the timing may be adjusted every time the setting of the pulse laser sources **2***a* and **2***b* is changed.

To deal with aged deterioration of the pulse laser sources, timing may be adjusted when the apparatus is started up or at a predetermined time, such as every morning. The time difference measured by the time difference counting circuit **12** may be constantly monitored by the CPU **11**, so that the timing is adjusted when the timing difference is outside the tolerance. The CPU **11** may store an accumulated emission count of the pulsed lights from the pulse laser sources **2***a* and **2***b*, and may adjust the timing when the count reaches a predetermined value.

In the present example, an individual difference of the delay from the emission of the pulsed light to the rise of the electric pulse signal, which the optical sensors **4***a* and **4***b* generate, is ignored, but the present invention is not limited to this. If the individual difference of delay is measured for the optical sensors **4***a* and **4***b* in advance and is reflected in the value of the excitation delay setting register, then the timing discrepancy of the pulsed lights irradiated onto the subject **1** can be decreased.

In this example, a case of generating the reference pulse signal **37** in the reference pulse generation circuit at a predetermined cycle was shown, but the method of generating the reference pulse signal is not limited to this, and the reference pulse signal may be generated synchronizing with another control signal. For example, the time difference "T**12**−T**08**" between the reference pulse signal generation and the electric pulse signal generation is stored when the emission timing is adjusted. The moving velocity of the probe **5** is assumed to be V in step S**6**. The reference pulse signal **37** is generated at a timing when the probe **5** passes a position at "V×(T**12**−T**08**)" before the measurement position. When time "T**12**−T**08**" elapses after the generation of the reference pulse signal **37**, the pulsed lights **22***a* and **22***b* are emitted. By this timing, the probe **5** advances "V×(T**12**−T**08**)", and has passed the area near the measurement position.

By synchronizing the reference pulse signal **37** with the position information of this probe **5** like this when the measurement is performed while moving the probe **5**, the pulsed light can be emitted at the same timing reaching the measurement position, and the positional accuracy of the measurement can be increased.

As described above, according to first example of the present invention, the starts of the flash lamps turning ON are shifted based on the timing discrepancy of the plurality of pulsed lights, and the interval between the oscillation start of the Q switch and the start of the flash lamp turning ON is kept constant. Thereby a plurality of timings of pulse emission is aligned while suppressing the fluctuation of light quantity. As a result, a phenomenon where a plurality of photoacoustic waves are generated from a same area in the biological tissue, and an artifact is generated in the diagnostic image, can be prevented.

SECOND EXAMPLE

Second example of the present invention will be described next. A difference of Second example from first example is that a timing is also adjusted when measuring a subject. This example is for supporting a case when the fluctuation of the emission timing is gradually increasing when pulsed light is irradiated onto the subject, due to the temperature rise inside the pulse laser source.

Description on the block diagram in FIG. **1** and the control signal generation circuit **30** in FIG. **3** is omitted since both are already described in first example.

An operation flow of a measuring apparatus of this example will now be described with reference to FIG. **7**. Description on step S**30** to step S**33**, which is the same as step S**1** to step S**4** in first example, is omitted. It is assumed that the values in the previous measurement are held in the register **31** in the control circuit **13** when step S**33** is completed. Description on step S**34** to step S**36**, which is the same as step S**6** to step S**8** in first example, is omitted.

Description on step S**37** to step S**40**, which is the same as step S**22** to step S**25** in first example, is omitted.

In step S**40**, if the time difference between the electric pulse signal **23***a* and the electric pulse signal **23***b* is within the tolerance, it is determined that the timings of the pulsed lights are matched, and processing advances to step S**41**. If this time difference is outside the tolerance, processing advances to step S**42**. Description on step S**41** and step S**42**, which is the same as step S**9** and step S**26** in first example, is omitted. Description on step S**43** to step S**45**, which is the same as step S**10** to step S**12** in first example, is omitted.

As described above, according to second example of the present invention, the value of the excitation delay setting register R**3** is updated every time the pulsed light is emitted when measuring a subject. Thereby the discrepancy of the timings of the pulsed lights **22***a* and **22***b* during measurement can be decreased. As a result, even if temperature rises during measurement and the characteristics of the pulse laser sources change, the generation of an artifact can be prevented. If the discrepancy of the pulsed lights is outside the tolerance in step S**40**, the acoustic signal data is not obtained in step S**41**, therefore even if a discrepancy of timings of the pulsed lights is unexpectedly generated during the measurement, the generation of an artifact on the diagnostic image can be prevented.

THIRD EXAMPLE

Third example of the present invention will be described next. A difference of third example from first example is that not only a timing of turning ON the flash lamp of the pulse laser sources, but also the interval from the turning ON the flash lamp to the oscillation of the Q switch is changed. By changing the interval from the lighting of the flash lamp to the oscillation of the Q switch, the quantity of the energy to be stored in the laser medium inside the pulse laser source is changed. This example allows to adjust the pulsed light to be irradiated onto the subject **1**. For example, in FIG. **1**, a strong photoacoustic wave may be generated from the surface of the plate member **6***b* in some cases when the quantity of pulsed light from the illumination optical system **3***b* is too strong. In this case, the photoacoustic wave, not from the subject **1**, wraps around the probe **5**, which may generate an artifact. A case of decreasing the quantity of pulsed light from the illumination optical system **3***b* to decreased this artifact, so that the quantity of pulsed light from the illumination optical system **3***a* is increased for the amount of the above decrease, will be described.

Description on the block diagram in FIG. **8**, which is the same as that of first example except for the light quantity measuring circuit **16**, is omitted. The light quantity measuring circuit **16** is a circuit for measuring the quantity of pulsed light using electric pulse signals **23***a* and **23***b* from optical sensors **4***a* and **4***b*. The light quantity measuring circuit **16** integrates the electric pulse signals **23***a* and **23***b* for each pulse emission, determines the intensity values of the pulsed light **22***a* and **22***b*, and stores these values in an internal register.

Description on the operation flow in FIG. **2** and the control signal generation circuit **30** in FIG. **3**, which is the same as first example, is omitted. A difference of this example from first example is the content of the emission timing adjustment processing in step S**5**. Details of the emission timing adjustment processing will now be described with reference to a flow chart in FIG. **9** and a timing chart in FIG. **10**. Description on step S**50** to step S**54**, which is the same as step S**20** to step S**24** in first example, is omitted. In the timing chart in FIG. **10**, time T**01** to time T**08** and time T**16** are the same as those in FIG. **4**.

Then in step S**55**, the CPU **11** accesses the light quantity measuring circuit **16**, reads the values of the light quantity P**22***a* of the pulsed light **22***a* and the light quantity P**22***b* of the pulsed light **22***b*, and stores these values in the internal memory.

Description on step S**56**, which is the same as step S**25** in first example, is omitted. If the time difference between the electric pulse signal **23***a* and the electric pulse signal **23***b* is within the tolerance, the CPU **11** determines that the timings of the pulsed lights match in step S**56**, and processing advances to step S**57**. If the time difference is outside the tolerance, processing advances to step S**58**.

In Step S**57**, the CPU **11** compares the light quantity P**22***a* and the light quantity P**22***b* with a tolerance which is set in the CPU **11** in advance, and determines whether these values are within the tolerance. If they are within the tolerance, the CPU **11** ends adjustment of emission timings since both the light quantities and time differences are within the tolerance. If at least one of P**22***a* and P**22***b* is outside the tolerance, processing advances to step S**58** and the CPU **11** continues processing.

In step S**58**, the CPU **11** changes the values in the register **31** so as to decrease the time difference which was read in step S**54**, and adjusts the quantity of the pulsed lights to be closer to a target value. The target value of the quantity of the pulsed light is determined in advance depending on the intensity of the photoacoustic waves from the plate members **6***a* and **6***b*, the frequency characteristics of the probe **5** and the like, and are assumed to be stored in the CPU **11**.

If it is determined that the light quantity P**22***a* is greater than the target value, the CPU **11** decreases the value of the oscillation delay setting register R**5** for the pulse laser source **2***a*, and decreases the excitation time so that the energy to be stored in the laser medium is decreased. If it is determined that the light quantity P**22***a* is smaller than the target value, on the other hand, [the CPU **11**] increases the value of the oscillation delay setting register R**5** for the pulse laser source **2***a*, and increases the excitation time so that the energy to be stored in the laser medium is increased.

Here the differences of the light quantity P**22***a* and the light quantity P**22***b* from the target value are called a "light quantity error" respectively, and are denoted by P**22***a*_E and P**22***b*_E. The CPU **11** subtracts "K1×P**22***a*_E" from the value of the oscillation delay setting register R**5** for the pulse laser source **2***a*. The CPU **11** also subtracts "K2×P**22***b*_E" from the value of the oscillation delay setting register R**6** for the pulsed laser light source **2***b*. K1 is a positive constant which indicates a control quantity to increase the light quantity of the pulse laser source **2***a*, and is adjusted in advance and is stored in the CPU **11**. K2 is a positive constant which indicates a control quantity to increase the light quantity of the pulse laser source **2***b*, and is adjusted in advances and is stored in the CPU **11**.

For example, if the value of the register **R5** is 150000 [ns] and K1×P**22***a*_E=−5000 [ns], the value of the register **R5** is changed to 155000. If the value of the register **R6** is 152000 [ns] and K2×P**22***b*_E=10000 [ns], the value of the register **R6** is changed to 142000.

If the value of P**22***a*_E is positive, the value of "K1×P**22***a*_E" also becomes positive, and the value of the oscillation delay setting register **R5** for the pulse laser source **2***a* becomes smaller than the value which was set in step **S51**. In other words, by the decrease of the excitation time, it is expected that the energy to be stored in the laser medium decreases, and the quantity of the pulsed light **22***a* decreases and approaches the target value.

If the value of P**22***a*_E is negative, the value of "K1×P**22***a*_E" also becomes negative, and the value of the oscillation delay setting register **R5** for the pulsed laser source **2***a* becomes greater than the value which was set in step **S51**. In other words, by the increase of the excitation time, it is expected that the energy to be stored in the laser medium increases, and the quantity of the pulsed light **22***a* increases and approaches the target value.

This is the same for P**22***b*_E and the oscillation delay setting register **R6** for the pulse laser source **2***b*.

The CPU **11** also writes an absolute value of a total of the value of the time difference "T**07**−T**04**" read in step **S54** and the value of "K1×P**22***a*_E−K2×P**22***b*_E" in the excitation delay setting register **R3**.

For example, if T**07**−T**04**=2200 [ns], K1×P**22***a*_E=−5000 [ns], and K2×P**22***b*_E=10000 [ns], then 12800 is written in the excitation delay setting register **R3**. If the total of the value of the time difference "T**07**−T**04**" and "K1×P**22***a*_E−K2×P**22***b*_E" is 0 or more, 1 is written in the selection setting register **R4**. If this value is negative, on the other hand, 0 is written in the selection setting register **R4**. For example, if T**07**−T**04**=2200 [ns], K1×P**22***a*_E=−5000 [ns] and K2×P**22***b*_E=10000 [ns], 0 is written in the selection setting register **R4**.

Processing then returns to step **S51** and the CPU **11** continues processing.

Then the reference pulse signal **37** is output at the time T**08**, which is 100 milli seconds after the time T**01**. Since the value of the excitation delay setting register **R3** is 12800, a pulse signal is output from the delay circuit **33** at 12.8 micro seconds after the time T**08** (at time T**24**). Since the value of the selection setting register **R4** is 0, a pulse signal is output for the excitation start signal **20***a* at time T**08**, and a pulse signal is output for the excitation start signal **20***b* at time T**24**. In other words, the start of turning ON the flash lamp of the pulse laser source **2***b* is 12.8 micro seconds delayed from the start of turning ON the flash lamp of the pulse laser source **2***a*.

The value of the oscillation delay setting register **R5** for the pulse laser source **2***a* is changed from 150000 to 155000 in step **S58**. Therefore the time difference "T**21**−T**08**" between the oscillation start signal **21***a* and the excitation start signal **20***a* becomes 155 micro seconds, which is a 5 micro second increase. Due to this, the energy storing time in the laser medium of the pulse laser source **2***a* becomes longer than the first time, and the quantity of the pulsed light **22***a* can be increased.

When a pulse signal is output for the oscillation start signal **21***a* at time T**21**, the Q switch turns ON in the pulse laser source **2***a*, and rapid amplification and oscillation of the excitation energy occur. Then the pulsed light **22***a* is output at several 100 nano seconds later (time T**22**). After several nano seconds of delay in the optical sensor **4***a*, the electric pulse signal **23***a* is output (time T**23**).

The value of the oscillation delay setting register **R6** for the pulse laser source **2***b* is changed from 152000 to 142000 in step **S58**. Therefore the time difference "T**25**−T**24**" between the oscillation start signal **21***b* and the excitation start signal **20***b* becomes 142 micro seconds, that is a 10 micro second decrease from the first time. Due to this, the energy storing time in the laser medium of the pulse laser source **2***b* becomes shorter than the first time, and the quantity of the pulsed light **22***b* can be decreased.

When a pulsed signal is output for the oscillation start signal **21***b* at time T**25**, the Q switch turns ON in the pulse laser source **2***b*, and rapid amplification and oscillation of the excitation energy occur. Then the pulsed light **22***b* is output at several 100 nano seconds later (time T**26**). After several nano seconds of delay in the optical sensor **4***b*, the electric pulse signal **23***b* is output (time T**27**).

In this example, the time differences "T**21**−T**08**" and "T**25**−T**24**" between the start of excitation and the start of oscillation are changed, whereby the energy stored in each pulse laser source is increased or decreased, so as to minimize the discrepancy of the quantity of the pulsed light and the target value. By shifting the excitation start timings of a plurality of pulse laser sources based on this change, the discrepancy of the timings of the pulsed lights can be prevented.

If the discrepancy of the emission timings of the electric pulse signals **23***a* and **23***b* and the discrepancy of the quantity values of the pulsed lights **22***a* and **22***b* become within the tolerance by this timing control, the emission timing adjustment processing ends. Then the pulsed light irradiation onto the subject is started by the processing in step **S6** and later (time T**16**). Here the CPU **11** does not change the register values inside the control circuit **13**, hence the pulse laser sources are controlled at the same timings as time T**08** to time T**16**. Reception of the photoacoustic signal is started synchronizing with the electric pulse signal **23***a* or the electric pulse signal **23***b* (time T**28**).

FIG. **11**A and FIG. **11**B show an example of a photoacoustic signal waveform and a diagnostic image according to this example. FIG. **11**A is an example of the photoacoustic signal which is output from the probe. The abscissa indicates time, and the ordinate indicates voltage. FIG. **11**B is a diagnostic image created by converting the photoacoustic signal.

In this example, the pulsed lights **22***a* and **22***b* are irradiated onto the subject **1** almost simultaneously at time T**28**. The interval of the excitation start signal and the oscillation start signal is adjusted so as to decrease the quantity of the pulsed light **22***b* in step **S58**. Thereby the photoacoustic waves generated from the surfaces of the plate member **6***b* and the subject **1** are weakened, and the voltages of the photoacoustic signals **51** and **52** decrease and converge in a short time. As a result, artifact **55** in the corresponding diagnostic image can be decreased.

Furthermore the interval of the excitation start signal and the oscillation start signal is adjusted so as to increase the quantity of the pulsed light **22***a* in step **S58**. Thereby the total of the quantity values of the pulsed lights **22***a* and **22***b*, which are irradiated to the light absorbing area **7**, remains unchanged, and the voltage of the photoacoustic signal **53** is approximately the same as the case of first example. As a result, the contrast of an image **56** in the diagnostic image can be maintained.

On the other hand, due to the increase of the quantity of the pulsed light **22***a*, the voltage of the photoacoustic signal **54**, generated from the surfaces of the plate member **6***a* and the subject **1**, increases more than the case of first example. The influence of the photoacoustic signal **54** on the diagnostic image, however, can be prevented by not using the signals after time **58**, when the photoacoustic wave generated from the surfaces of the subject **1** and the plate member **6**a propagates, for generating the diagnostic image.

In this example, a case of adjusting the emission timing before measuring the subject was described, but the emission timing may be adjusted during measurement just like second example. Thereby the discrepancies of the quantity of the pulsed light and the timings due to the rise of temperature of the pulse laser sources during measurement, and other causes can be decreased, and an image with less artifacts can be obtained.

For the index to change the excitation time, the integrated values of the electric pulse signals from the optical sensors **4**a and **4**b, was used in this example, but the present invention is not limited to this method. For example, the photoacoustic signal **51** from the plate member **6**b is detected by the signal processing circuit **14**, and the value of this voltage is compared with an allowable value stored in the CPU **11**. If the voltage of the photoacoustic signal **51** is greater, the excitation time is controlled to be decreased. If this method is used, artifacts can be decreased with certainty by using a photoacoustic signal, which directly influences the diagnostic image, as the index.

As described above, according to third example of the present invention, if a light quantity error is generated in the first emission, the interval of the excitation start signal and the oscillation start signal is controlled to cancel the light quantity error. The values of the excitation start delay register are set so that the interval controlled at this time and the discrepancy of the timings measured for the first time are both cancelled.

Thereby the energy stored between the turning ON the flash lamp of each pulse laser source **2**a and **2**b and the start of the Q switch can be controlled, and each quantity of pulsed light can be matched with the target value. By changing the oscillation start timing considering the space of the flash lamp and the Q switch, the timings of a plurality of pulsed lights can be matched at high precision. As a result, both artifacts generated by a discrepancy of the light quantity and a discrepancy of the timings can be decreased, and a higher quality diagnostic image can be obtained.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2010-102312, filed on Apr. 27, 2010, which is hereby incorporated by reference herein in its entirety.

The invention claimed is:

1. A measuring apparatus comprising:

a plurality of laser sources for generating pulsed lights;

a control unit for controlling excitation start timing(s) of said laser sources by outputting an excitation start signal to respective ones of said laser sources, and controlling oscillation start timing(s) of said laser sources by outputting an oscillation start signal to ones of said laser sources after a predetermined time has elapsed from the output of the excitation start signal, so as to generate pulsed lights from said laser light sources;

an acoustic wave receiving unit for receiving an acoustic wave generated in a subject by irradiation of the subject with the pulsed lights; and

a signal processing unit for obtaining information of the subject, using a signal which is output from said acoustic wave receiving unit, wherein

said plurality of laser sources include a first laser source and a second laser source of which preparation time from the start of the excitation to the generation of the pulsed light is longer than that of said first laser source, and

said control unit sets timing of outputting the excitation start signal to said first laser source to follow timing of outputting the excitation start signal to said second laser source according to a difference of the preparation time between said first laser source and said second laser source.

2. The measuring apparatus according to claim **1**, wherein said control unit sets the timings of outputting the excitation start signal to said first laser source to follow the timing of outputting the excitation start signal to said second laser source so that a difference of between the timings of generation of the pulsed light from said first laser source and the timing of generation of the pulsed light from said second laser source is within a predetermined tolerance.

3. The measuring apparatus according to claim **2**, further comprising a detecting unit for detecting a difference of the timings of generation of the pulsed light from said first laser source and the timing of generation of the pulsed light from said second laser source,

wherein said control unit sets the timings of outputting the excitation start signal to said the first laser source to follow the timing of outputting the excitation start signal to said second laser source so that the difference of the timings of generation of the pulsed light detected by said detecting unit is within the tolerance.

4. The measuring apparatus according to claim **3**, wherein said signal processing unit does not use a signal that is output from said acoustic wave receiving unit for obtaining information of the subject when the difference of the timings of generation of the pulsed light detected by said detecting unit is outside the tolerance.

5. The measuring apparatus according to claim **3**, further comprising a light interrupting unit for interrupting the pulsed lights irradiated from said sources to the subject, while said control unit is adjusting the difference of the timings to output the excitation start signal.

6. The measuring apparatus according to claim **1**, wherein

said acoustic wave receiving unit performs measurement while moving, and

said control unit determines timing of outputting the excitation start signal to one of said laser sources so that timing when said acoustic wave receiving unit reaches a measuring position and timing of generation of a pulsed light are synchronized.

7. The measuring apparatus according to claim **1**, further comprising a light quantity measuring unit for measuring light quantity of pulsed light generated from each of said laser sources,

wherein said control unit changes a length of time between the timing to output the excitation start signal and the timing to output the oscillation start signal so that the light quantity measured by said light quantity measuring unit approaches a predetermined target value.

8. The measuring apparatus according to claim **1**, wherein said control unit changes a length of time between the timing of outputting the excitation start signal and the timing of outputting the oscillation start signal so that an intensity of the signal which is output from said acoustic wave receiving unit becomes smaller than a predetermined allowable value.

9. A measuring apparatus comprising:

a plurality of laser sources for generating pulsed lights;

a control unit for controlling excitation start timing(s) of laser sources of said plurality of laser sources by outputting an excitation start signal to respective ones of said laser sources, and controlling an oscillation start timing of the respective ones of said laser sources by outputting an oscillation start signal to the respective ones of said laser sources after a predetermined time has elapsed from the output of the excitation start signal, so as to generate pulsed lights from said laser sources;

an acoustic wave receiving unit for receiving an acoustic wave generated in a subject by irradiation of the subject with the pulsed lights; and

a signal processing unit for obtaining information of the subject, using a signal which is output from said acoustic wave receiving unit, wherein

said plurality of laser sources include a first laser source and a second laser source, and

said control unit makes a timing of outputting the excitation start signal to said first laser source different from a timing of outputting the excitation start signal to said second laser source.

10. The measuring apparatus according to claim 9, further comprising a detecting unit for detecting a difference of the timings of generation of the pulsed light from said first laser source and the timing of generation of the pulsed light from said second laser source,

wherein said control unit sets the timings of outputting the excitation start signal to said the first laser source to follow the timing of outputting the excitation start signal to said second laser source so that the difference of the timings of generation of the pulsed light detected by said detecting unit is within the tolerance.

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